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UNITED STATES
DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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INFORMATION CIRCULAR

DEWATERING AND DRYING OF COAL

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BY

JAMES R. CUDWORTH AND ELLIS S. HERTZOG

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

DEWATERING AND DRYING OF COAL[1]

By James R. Cudworth[2] and Ellis S. Hertzog[3]

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INTRODUCTION

Tremendous interest has been evidenced in the subject of dewatering and drying coal for the past 10 years, and yet little effort has been made to summarize the literature, at least so far as this country is concerned. Only a few published articles have dealt solely with dewatering and drying coal. In most cases the subject has been discussed briefly, either in general terms or as to specific installations.

It is desirable that a compendium be prepared collecting in one place information on the dewatering and drying of coal, the needs for this process in various fields, the available equipment, and the current American practice in regard to it. This work was undertaken by the Bureau of Mines in cooperation with the University of Alabama. New coal-washing plants in which various types of dewatering and drying equipment were in operation were visited in Pennsylvania, Ohio, Indiana, and Illinois.

The dewatering and drying of coal has been studied in this country by the Surface Preparation Committee of the Coal Operators' Committee of the American Mining Congress. In Germany it has received the special attention of the Reichskohlenrat, and in Great Britain of the Utilization of Fuel Committee of the Institute of Mining Engineers.

ACKNOWLEDGMENTS

The authors acknowledge the kind cooperation of the officials and staff members of the coal mining companies whose plants were visited. Officials of various drying-equipment companies and staff members of research bureaus have contributed helpful suggestions. A. C. Fieldner and H. F. Yancey, of the Bureau of Mines, have assisted the authors greatly by their comments. J. B. Morrow, preparation manager of the Pittsburgh Coal Co., has especially aided the authors with his suggestions.

ADVANTAGES OF DEWATERING AND DRYING IN VARIOUS FIELDS

General Coal-Washing Practice

In the wet preparation of coal it has long been recognized that draining or dewatering of the finer sizes constitutes a major problem and, with the increased market for these sizes for various uses, washeries have been equipped with devices to reduce the moisture content. To a large extent today industries using pulverized fuel, such as the cement and electrical plants, have combined heat-drying with the pulverization of coal. The utilization of pulverized fuel for firing has led to the erection of a number of sludge-drying plants abroad, thus utilizing what was formerly a waste product. It is not hard to conceive of such a step in this country in the future. Two common problems of coal-washing practice that are intimately connected with dewatering and drying are the clarification of washery water and the prevention of stream pollution. The first field has been studied from many angles, including the use of coagulating agents followed by vacuum filters to remove the solids, and the use of sludge tanks

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with dewatering screens incorporated therein. In many districts, the disposal of sludges into streams has been stopped by stream-pollution laws. The lack of space for impounding sludges in private ponds has been a problem in other districts. Both of these conditions have made the dewatering of sludge necessary. In Europe[4] it has been found that removing dust from coal prior to washing it reduces the slimes produced in the washing water, accelerates the dewatering rate, and facilitates the clarification of the washery water by removing the fine particles of coal and dirt. This advantage is mentioned by H. F. Hebley,[5] who states that dedusting coal prior to cleaning it would have the advantage of removing the troublesome fraction of the feed and facilitating drainage. If the dust so removed has a low ash content, it can be remixed with the clean fine sizes, thus increasing the yield and decreasing the moisture content.

Transportation and Handling

There is need for dewatering coal in connection with the transportation of washed fine coal or washed slack, because these sizes have much greater capacity for holding moisture than do the larger sizes. That reduction in moisture content means a saving in freight costs is self-evident, but this is not the only reason for dewatering before transportation. Increasing demand for fine-sized domestic fuel and for finer sizes for metallurgical practice has resulted in increased dewatering and drying in order to eliminate difficulties in unloading and storing. Excess moisture in the coal causes it to hang to the sides of cars and bins and to clog chutes. This condition is aggravated by freezing in localities where severe climatic conditions prevail. Probably 2 percent of surface water is the minimum that will cause much trouble due to freezing.[6] This figure refers to the size ranges commonly used for coking.

Preparation of Coal for Manufacture of Gas

In regard to the advantages of dewatering and drying coals to be used in the production of manufactured gas, it should be pointed out that excess moisture in coal has a chilling effect[7] on the walls of the retorts, makes the coal difficult to charge mechanically, and complicates the system for condensing and disposing of waste liquor.

4/ Myers, E. M., The Dedusting of Coal: Proc. Illinois Min. Inst., 1933, pp. 42-46.

5/ Hebley, H. F., Advantages and the Use of Dedusted Coal and Its Products: Proc. Illinois Min. Inst., 1933, pp. 77-86.

6/ Fieldner, A. C., Influence of Washing Coal on Coke Properties and on Gas and Byproduct Yields: Rept. of Investigations 3020, Bureau of Mines, 1930, p. 11.

7/ Drying of Washed Coal, Notes from Memo No. 18, Utilization of Coal Committee of the Institute of Mining Engineers: Fuel Econ., vol. 11, no. 124, January 1936, p. 150.

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Preparation of Coal for Manufacture of Coke

The literature contains numerous references to the need for dewatering and drying in preparing coal for metallurgical coke. The effect of dewatering and drying of coal before coking has been studied. It has been recognized that any excess moisture in coal for coking is a burden on the oven. This moisture must be evaporated in the oven before actual coking proceeds. Statistics[8] have been published showing the net thermal efficiency of the older types of coke ovens as 40 to 50 percent and of the newer types as 60 to 75 percent, as compared with as high as 90 percent in an external dryer. Moreover, the time consumed in evaporating the moisture in an external dryer is considerably less than that required for the same percentage of moisture to be evaporated in a coke oven. Then, there is a further advantage of getting greater capacity per oven through reduction of coking time. The increase in the rate of heating also increases the yields of byproducts.

Another influence[9] that the moisture content of the slack coal exerts upon the coking process is the effect upon the bulk-density of the coke. Malleis[10] has stated that the main effect of excess moisture in coal mixtures going to the byproduct oven is to lower the bulk-density of the moist coal, especially in the case of fine pulverization, and that the lower weight of the oven charge results in decreased capacity as well as the production of "lighter" coke. The moisture content of the slack coal appears to have more influence upon the bulk-density of the coke than on the size analysis of the coal, and control of the moisture content is an important means of maintaining standard conditions of coking and quality of products. In a paper discussing the influence of wet preparation of coal on coke properties, Fieldner[11] calls attention to one of the adverse factors in carbonizing wet coal, as that of a reduction of oven capacity due to the fact that "the surface water dilutes and expands the coal to a certain percentage (about 7 percent), causes the smaller particles to stick to the larger pieces, and prevents them from filling voids." He also notes that excessive surface moisture (12 to 15 percent total moisture in low-moisture coals) affects the quality of the coke and injures the oven walls. R. V. Farnham[12] has stated that the reduction of the moisture content to a desirable minimum in the charge and the temperature of the charge itself where it enters the coke oven are of primary importance in control. Both of these are intimately connected with the dewatering and drying operations

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8/ Work cited in footnote 7, p. 150.
9/ Colliery Guardian, Drying of Washed Coal, Utilization of Coal Committee: Inst. of Min. Eng., London, England, vol. 150, Dec. 6, 1935, p. 1037.
10/ Malleis, O. O., Characteristics Affecting the Selection of Coals for the Manufacture of Coke: Proc. 13th Fuel Engineers' Meeting Appalachian Coals, Inc., Cincinnati, 1936, pp. 10-11.
11/ Work cited in footnote 6, p. 3.
12/ Farnham, R. V., The Drying of Coking Coals: Col. Guardian, vol. 149, 1934, p. 1043.

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in the preparation of the coal. Another statement of the advantages of drying coal preliminary to coking has been given by Mott[13]. These advantages are:

1. Evaporation in an external dryer is done more efficiently and it therefore reduces the net fuel consumption.

2. Drying reduces the coking time by 20 minutes to 1 hour for each percent moisture removed and so increases the coking capacity and the benzol, gas, and tar yields.

3. It reduces the wear on the oven walls by spalling due to water drainage.

4. It decreases the amount of liquor to be handled, evaporated, and to be disposed of as a troublesome effluent.

Briquetting

Although the production of briquets from coal is much less widespread in the United States than in Europe, it should be pointed out that it has long been common practice to dry the coal by the use of heat driers in the manufacture of briquets. P. O. Rosin and E. Rammler,[14] in a comparatively recent article, have stated that a high and uniform degree of dryness is one of the important factors in producing better briquets with binders, and that an even more severe drying treatment is necessary to make briquets without binders. There have been many new developments in this field in recent years. Experience in the briquetting of brown coal abroad has shown that the quality of the briquets depends to a high degree on the preparation of the coal and correct control of the drying process.

In Germany the briquetting of brown coal is considered one of the most important applications of heat-drying of coal,[15] and the drying is the most important economic angle of this briquetting process; in fact, the drying technic as now applied to other fields abroad received its greatest impetus in the briquetting processes. The making of briquets from our American lignite deposits will, no doubt, call for similar heat-drying processes.

CLASSIFICATION OF MOISTURE IN COAL

The literature contains various terms that have been applied by different investigators to the classification of moisture in coal, namely, inherent, bed, superficial, surface, free, and others, with the result that

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13/ Mott, R. A., The Drying of Coal at the Barrows Collieries: Fuel Econ., vol. 7, no. 73, October 1931, pp. 33-37.

14/ Rosin, P. O., and Rammler, E., Contribution to the Drying of Coal: Jour. Inst. Fuel, vol. 9, no. 48, August 1936, p. 363.

15/ Reichskohlenrats, Die Trocknung und Entwässerung von Kohle: Julius Springer, Berlin, 1936, p. 43.

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there is confusion as to the exact meanings intended. For a study of dewatering and drying of coal, a system of classification of moisture is desirable, based on the manner in which the water is held by the coal. From this point of view, moisture in coal can be classified under two main headings, namely, inherent moisture and superficial (or surface) water.

Inherent Moisture

Any piece of coal that appears to the naked eye to be free from cracks or fractures is, in reality, permeated with a dense network of fine capillary pores that extend throughout every part of the pure coal substance. These pores are estimated to have diameters as small as 1 to 0.1 micron.16/ The capillaries may be compressed remnants of ducts and cells that were present in the plants from which the coal was formed, or they may be spaces between colloidal particles, or even intermolecular spaces. Water present in these capillaries is known as inherent moisture. Although any water present in these capillaries may be classed as inherent, the term "inherent moisture", as generally used, implies that the capillaries are filled and in equilibrium with air saturated with water. This postulates an idealized condition closely approached by coal freshly mined from a newly exposed face on which there is no visible surface water, and, therefore, the term "bed moisture" is more or less synonomous with the term "inherent moisture."

Inherent moisture is regarded as being a part of the true coal substance, having been present in the peat from which the coal was formed and having been reduced in amount as the coal slowly changed from peat to brown coal, then to lignite, and so on up through the series. However, if the coal were dried artificially and then soaked in water to refill the capillaries, the water present in them would still be regarded as inherent as far as the drying problem is concerned. If the capillaries are partly emptied by drying they exhibit a greatly reduced vapor pressure, and in consequence the coal becomes hygroscopic.

A few definitions of certain terms as given by various authorities may be helpful at this point. Porter and Ralston state:17/ "By the expression 'inherent water' in coal or in any material, therefore, is meant the water which exists as such but which has a vapor pressure less than normal."

Stansfield and Gilbart say,18/ "It is assumed here that the true moisture of the coal is the minimum amount of water in the fresh coal which can exert the same vapor pressure as free water at the same temperature. Any additional water has the same vapor pressure as free water, but any

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16/ Reichskohlenrats (work cited in footnote 15, p.

17/ Porter, H. C., and Ralston, O. C., Some Properties of the Water in Coal: Tech. Paper 113, Bureau of Mines, 1916, p. 9.

18/ Stansfield, Edgar, and Gilbart, K. C., Moisture Determination for Coal Classification: Trans. Am. Inst. Min. and Met. Eng., Coal Division, 1932, p. 136.

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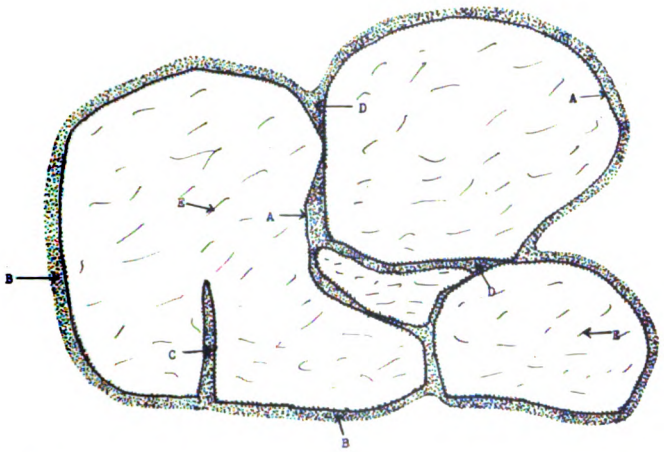

A = Adsorbed Water.
B = Adherent Water.
C = Macrocapillary Water.
D = Interstitial Capillary Water.
E = Inherent or Microcapillary water.

Figure 1.

Figure 1.—Kinds of surface moisture.

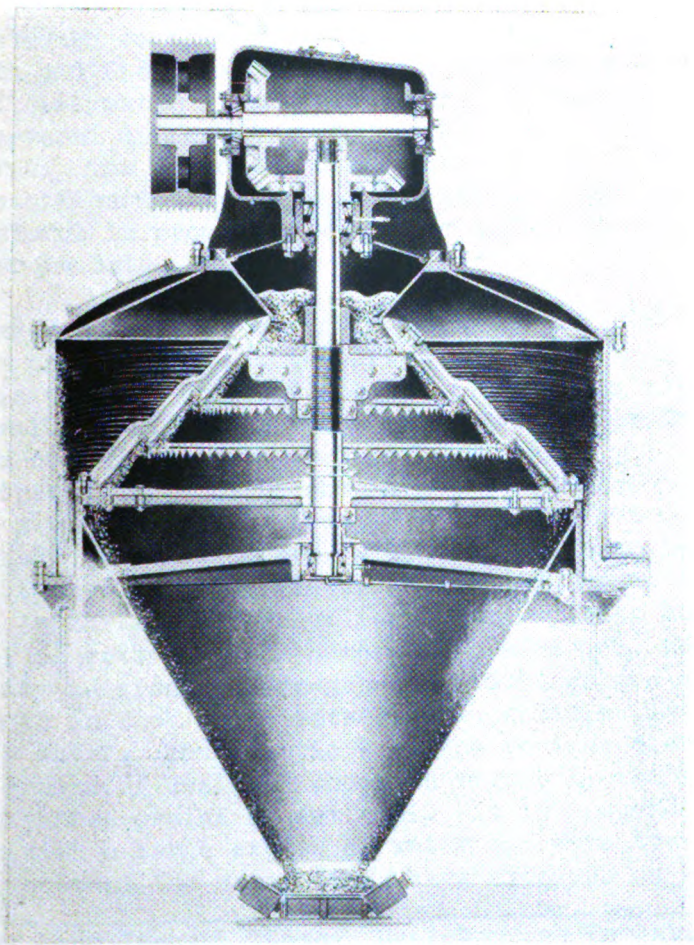

Figure 2.—The Carpenter centrifuge (courtesy of the Koppers—Rheolaveur Co.).

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removal of water below this point is at once indicated by a reduction of vapor pressure." Yancey and Fraser[19] make the following statement: "Low-rank bituminous coal may contain 15 percent of moisture and yet be substantially dry and dusty. Such water has been termed 'inherent' or 'hygroscopic' as distinguished from that which gives coal a wet appearance; the latter is called 'surface moisture'."

The terms "inherent moisture", "hygroscopic moisture", "bed moisture", "true moisture", and "moisture-holding capacity", are practically synonomous. Inneres Wasser and Innenkapillarwasser in German terminology denote the same conception.

Inherent moisture can be partially removed from coal by air-drying at normal temperatures, but anything approaching complete removal requires the use of heat-drying. Inherent moisture is not removed by drainage hoppers, bucket elevators, dewatering screens, or centrifuges except when they are combined with some type of heat-drying.

Superficial Water

Any water attached to the surface of the coal, together with that retained in cracks and fissures (of a size visible to the naked eye), is classed as superficial water or surface water. Surface water may be classified into several different kinds, as has been done in Germany by the Reichskohlenrat. The following classification[20] follows their system. Although this classification is perhaps not directly applicable in a practical way, yet it is helpful in promoting a clearer understanding of the manner in which the water is held.

The inner layer of surface water is bound to the coal by adsorption and clings to the coal with great tenacity. However, this layer, called adsorbed water, is probably only of molecular thickness and its total amount is very small. Outside the very thin layer of adsorbed water is a much thicker film of water, which is held by adhesion and surface tension; this is called adherent water. It should not be understood that there are two separate and distinct shells of water - the adsorbed water and adherent water probably shade into each other. The water present in cracks and fissures is held there by the previously mentioned forces combined with capillarity, and is called macro-capillary water. Water between the lumps or grains of coal is held there by adsorption, adhesion, and capillarity; and the capillarity is greatly strengthened around points of contact of the grains. Water held in such voids between the particles is called interstitial capillary water. The locations of the various classes of water in relation to the grains of coal are shown in figure 1, which is a much enlarged diagram of three grains of wet coal. It is assumed that the grains had been treated with a large excess of water and were then allowed to drain naturally, so that the water films have attained an equilibrium. The

19/ Yancey, H. F., and Fraser, Thomas, Coal-Washing Investigations: Methods and Tests: Bull. 300, Bureau of Mines, 1929, p. 233.
20/ Reichskohlenrats (work cited in footnote 15, pp.

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water attached to the coal will not drain away under the influence of gravity as long as the system is not disturbed. Any additional water added to the space above D would drain away, leaving the system in the same condition as before. Air-drying would remove the films down to the adsorbed layer, but they would be permanent in air saturated with moisture.

Effect of Size and Surface Area on Dewatering

Since the problem of dewatering or draining coal deals primarily with the removal of superficial water, experimental work on dewatering at first was devoted to studies of the amounts of moisture retained after natural drainage of sized and unsized coals of various ranges, for different periods of draining time. The void spaces in coarse sized coal are sufficiently large to allow rapid draining by gravity of the water held between the coal particles. Mott[21] has stated that the percentage of surface water retained depends upon (a) the size of the interstices and (b) the proportion of the total apparent volume of the coal pile which they occupy. He states further that experiments have shown that

1-1/2-inch to 1/10-inch graded coal will hold 1.6 to 10 percent water.
1/10-inch to 1/100-inch graded coal will hold 10 to 50 percent water.
-1/100-inch graded coal will hold 50 percent water.

Mott also concludes that the interstitial space usually amounts to about 57 percent for all grades of closely sized coal when loosely piled, but can be reduced to about 47 percent by agitating the coal (pressure piling). The difficulties of dewatering are greater with mixtures of sizes and increase with increasing percentages of extremely fine sizes of coal or clay.

It is apparent that the dewatering of coal coarser then, say, 1/2 inch is accomplished readily by natural drainage, with the emphasis laid on that type of installation that will occupy the least space, the lowest power consumption, and the lowest initial and operating cost. As Prochaska[22] points out, "the continuous stream of coal coming from the mine does not allow, except at high cost, the devoting of much time to any one separate stage of its preparation."

For the dewatering of fine coal the amount of surface for bonding the water and the smaller size of the interstices makes the problem more difficult, for the time required for any effective reduction of surface water by natural drainage becomes too great and must be accelerated mechanically or by heat drying. Prochaska[23] notes that the selection of a dewatering method for fine-coal dewatering should consider the character of the fine coal and the slate.

21/ Mott, R. A., The Dewatering and Drying of Coal: Trans. Fuel Conference, World Power Conference, London, 1928, vol. 1, pp. 341-358.
22/ Prochaska, Ernst, Coal Washing: McGraw-Hill Book Co., New York, 1921, p. 266.
23/ Prochaska, Ernst, work cited in footnote 22, p. 266.

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DEWATERING OF COAL

It is proposed in this paper to outline the various methods of dewatering and drying, some of which have been in use for many years, others of which are innovations in coal-washing practice. The choice of dewatering and drying practice depends mainly upon (1) the size of the coal to be treated, (2) amount of moisture reduction desired, and (3) the size of the washery. Considering, first, the question of dewatering coarse coal, say plus 1/2-inch, where the process is relatively inexpensive and simple, there are available the following mechanical methods: (a) railroad cars, (b) drainage hoppers and bins, (c) conveyors with wedge-wire openings or wire-screen plates, (d) bucket elevators with perforated buckets, (e) shaking screens, and (f) stationary screens. This class of coal will include many ranges of commercial sizes such as are demanded by the market in various districts. T. W. Guy[24] divides this class into two size ranges - (1) mean sizes 1-1/2-inch to 3-1/2-inch (large coals), and (2) mean sizes 1/2-inch to 1-1/4-inch (intermediate coals) - with results reported showing the surface moisture in the products ranging from 0.3 to 3.0 percent in the large coals and 1.8 to 5.5 percent in the intermediate coals.

For the dewatering of finer sizes - minus 1/2-inch - some of the equipment used on the coarser sizes is employed, and, in addition, (a) centrifuges, (b) suction filters, and (c) dewatering elevators and screens in connection with settling tanks. In the same article mentioned above, T. W. Guy[25] has divided the finer sizes into mean sizes, 3/16 inch to 3/8 inch, 0.023 inch to 0.185 inch, and 0.008 inch to 0.023 inch, with final surface-moisture results reported of 9 to 19 percent for screens and conveyors (with a further reduction to 4 to 7-1/2 percent by centrifuging), 18 to 45 percent for high-speed screens, and 18 to 22 percent for vacuum filters in the respective classes. Results given in this paper show that in American dewatering practice elevators, conveyors, and screens are used over the widest range of sizes from 4-1/2-inch coal to about 28-mesh, and centrifuges, as reported, are used on minus 4-mesh material. Filters, which as yet are not a common type of installation, are used on material finer than 48-mesh.

Natural Drainage - Railroad Cars, Bins, Hoppers, and Pits

The natural drainage of nut coals and larger sizes in cars, bins, hoppers, and pits is readily accomplished, as the void spaces are sufficiently large practically to exclude capillary water being held between the lumps.[26] The total time required for drainage depends upon the time necessary for the water in the upper layers of the coal to reach the bottoms of the bins. In general, natural drainage is rapid and complete for coals coarser than 1/2 inch to 3/8 inch. However, if the coal contains a considerable

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24/ Guy, T. W., Methods and Performances in Dewatering and Drying Washed Coal: Coal Mine Mechanization, Year Book 1937, Am. Min. Cong., p. 211.

25/ Guy, T. W., work cited in footnote 24.

26/ Chapman, W. R., and Mott, R. A., The Cleaning of Coal: Chapman & Hall, London, pp. 269-270.

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proportion of fine coal, the mixture in the bin requires more time for draining and gives less moisture reduction than a closely sized product. Natural drainage is also limited by the presence of fine clay particles, which hold more water than do coal particles and form impermeable layers, which, in some cases, stop natural drainage. According to Rzezacz,[27] coal containing fine sizes of coal and clay is likely to give a product of widely fluctuating moisture content. The material segregates into different horizontal layers; the spaces in the lower coarse layers become filled with finer and finer material, which acts as a filter, and finally become coated with a top layer of fine mud. This layer of coal and mud becomes so compact, due to pressure exerted by the weight of the coal above it, that the dewatering is practically stopped. Under such conditions it is preferable first to dewater with screens, drainage belts, or bucket elevators, desliming in this way, and then to dewater in the drainage hoppers. The usual procedure is for the washed fine coal to pass from the wash boxes to a washed coal sump, from which it is removed by a drainage elevator. This discharges the coal onto a scraper conveyor, which passes it to drainage hoppers. The objections to this type of layout are mainly choking of the perforations in the drainage elevator, relatively inefficient water removal, and slime discharged with the surplus water from the sump. The omission of the drainage conveyor may cause large amounts of water to be fed to the drainage hoppers.

Drainage Conveyors and Bucket Elevators

Scraper conveyors that drag the coal from the pit or boot up an incline in which are inserted dewatering screens are quite commonly used in some districts as well as horizontal conveyors with dewatering screens. The speed of the conveyor is timed to allow natural drainage. The Baum drainage conveyor consists of a moving drainage belt that allows natural drainage with auxiliary squeezing of the coal against vertical partitions. The coarse coal is fed into the bottom of conveyor, with the finer sizes on top. The Baum conveyor has been used mainly in Europe, but in recent years it has been largely replaced with simpler and cheaper equipment.

Bucket elevators have been mentioned already in connection with conveyors. They are used frequently in this country when it is desired to combine dewatering with elevation of the drained product. In some cases, vibrators are used to assist in dewatering through a reduction of closing of the perforations.

Stationary Screens

Wedge-wire screens are used commonly for dewatering fine coal, either auxiliary to other drying equipment or alone. The wedge-wire spacing varies from 1-1/2 mm to 1/5 mm in common practices. In one installation[28]

27/ Rzezacz, P., Die Trocknung der Feinkohle durch Schleudern: Glückauf, May 1937, p. 497.

28/ Barley, S. B., and Parmley, S. M., Dewatering Coal: Coal Age, October and November 1935, vol. 40, no. 10, pp. 407-410; vol. 40, no. 11, pp. 458-461.

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the troughs of the drag conveyors have 3-foot steel wedge-wire sections spaced every 8 feet between blank plates, which allow intervals for draining and squeezing. The wedge wire for minus 1-inch coal has 3/16-inch spaces and for 3/8-inch by 0 coal, 1/8-inch spaces. The dewatering attained is as follows:

Washed coal 3/8 inch by 4 inch 3 percent moisture as loaded in railroad cars.
Washed coal 2 inch by 4 inch 1.5-2.3 percent moisture as loaded in railroad cars.
Washed coal 1 inch by 2 inch 3.1 percent moisture as loaded in railroad cars.
Washed coal 3/8 inch by 1 inch 4.5 percent moisture as loaded in railroad cars.
Washed coal 3/8 inch by 1 inch 3.8 percent moisture as loaded in railroad cars.

The controlling factors include the percentage of finer sizes, the thickness of the bed on the conveyor or the speed of the conveyor, the area of the screening surface, and the total length of the dewatering section. Wedge-wire stationary screens are also used to drain coal partially preliminary to using other dewatering units, such as centrifuges, or following dewatering bucket elevators. Wedge-wire screens are manufactured in steel, iron, brass, etc., to meet individual requirements.

Shaking Screens

Shaking screens are used in many plants in the United States, particularly for dewatering sizes larger than 3/8 inch. In the anthracite fields they constitute the principal method of dewatering and give excellent results, especially when sufficient screening surface is used. Greater efficiency in the removal of undersize and thereby more complete dewatering is obtained by the use of water sprays in conjunction with shaking screens. Higher efficiency in dewatering is obtained by not attempting to drain through several superimposed screens. Sometimes vibrators and hot-air blowers are used in connection with shaking screens to increase the reduction of moisture. The shaking screens can be divided into two general groups on the basis of the type of stroke. The older type of shaking screen is the low-speed, long-stroke shaker whose principal function was sizing, while the new type is the high-speed, short-stroke shaker with wedge wire, which is primarily a dewatering screen. The screening surfaces range from perforated plates for coarse sizes to wedge-wire and slotted screens for medium and finer sizes. The screens are of steel, bronze, stainless steel, and special alloys, depending upon the individual installations. The usual shaking-screen unit consists of a steel frame upon which is mounted the screening surface. The frame usually is driven by eccentrics through wooden or steel arms and is supported or hung by flexible supports, which are often wood. The dewatered coarse coal generally goes directly to the mixing conveyor or to the loading booms. The use of shaking screens on the dewatering of fine-sized coal has been in practice for many years, particularly in Europe, where it is common to treat even slurry in this manner. It is advantageous to treat slurry separately from fine coal, as the efficiency of the dewatering operations is reduced by the excess water held by the slurry. In most installations where centrifuges or heat driers are used, the coal is first partially dewatered on shaking screens. Shaking screens are also used to dewater the effluent from centrifuges and for sludge. The slope of the screen apparently is as important a factor as is adequate screening area. The life of the

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screen can be increased materially by selecting proper screening cloths or plates for this duty. In some large installations vibrating screens are used (instead of shaking screens) for dewatering; the results are similar. Some figures recently released by T. W. Guy[29] on dewatering washed coals show the following results on shaking screens:

No.	Size of Product Dewatered: Range	Size of Product Dewatered: Mean	Percent surface moisture
1	2 inch by 4 inch	3.00	1.1
2	2 inch by 3 inch	2.50	1.5
3	1-1/8 inch by 2 inch	1.56	1.8
4	3/8 inch by 2 inch	1.18	3.6
5	3/8 inch by 1-1/4 inch	.81	4.2
6	28-mesh by 7/16 inch	.23	11.5
7	48-mesh by 5/16 inch	.156	16.6
8	60-mesh by 14-mesh	.027	23.3

Where the final moisture desired on fine-coal slack is below approximately 10 to 15 percent and where transit is short, it is necessary to install dewatering equipment of different types such as centrifuges or heat driers.

Centrifuges

General Considerations

The centrifugal drier for coal is an adaptation of centrifuges that have been used for the dewatering of other products for many years. Many examples of centrifugal coal driers have been developed both in this country and abroad. In general, they can be classified into vertical and horizontal axis types, depending on the position of the axis of rotation of the sieve basket or centrifuging body. The Haberman, Simplex, Humboldt, and Laughlin belong to the horizontal axis type, while the Wendell, Carpenter, Elmore, Bemag, Hoyle, Fesca, Meguin, Reineveld, and Wedag are of the vertical type. Of the two types, those with vertical axes have been used most widely. Practically all of the machines in use today for dewatering coal are of the continuous type, in which the coal passes through the centrifuge in a steady unbroken stream. In comparison with other drainage devices for fine coal of the same size range, centrifuges have large capacity together with small space requirement. They dewater rapidly and produce a drier product than any other method in which heat is not employed. In the use of centrifuges, two disadvantages formerly mentioned in the literature were the rapid wearing out of the screens or dewatering plates and the difficulty of making repairs. Practically all of the latest type machines use case-hardened or armored parts and use screens made of especially resistant material, so that they last many times longer than did the earlier

29/ Guy, T. W., Methods and Performances in Dewatering and Drying Washed Coal: Coal Mine Mechanization Year Book, 1937, published by the American Mining Congress, Washington, D. C., pp. 211-217.

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types. The requirements of centrifuges for coal have been stated by Barley and Parmley,30/ as follows:

> (1) A large capacity, (2) a low maintenance and operating cost, (3) high-water removal, (4) small loss of coal in the effluent, (5) low power cost per ton treated, and (6) the lowest possible breakage of plus 4-mesh material into smaller sizes.

In addition to the foregoing, these authors point out:

> It is essential to have a machine of continuous type which will give a uniform moisture content as well as consistent physical and chemical properties.

The driers mainly used in the United States have been the Elmore, Wendell, and Carpenter. At the present time the Carpenter described below is used almost universally, but the Elmore is also used in at least one installation in this country.

Carpenter Centrifuge

The design of the Carpenter centrifuge, illustrated in figure 2, is comparatively simple as to moving parts. It employs no scrapers to move the coal and so eliminates many mechanical parts present in other centrifuges. The Carpenter drier consists of a truncated cone made up of a series of sieve bands fastened to a vertical shaft by spider castings. The shaft is driven by a V-belt drive connected to a motor that is attached to the housing enclosing the rotor or sieve basket. The wet coal is fed from a hopper on top of the machine onto a horizontal distributing disk attached to the vertical shaft of the rotor, from which it is flung to the first sieve band. The distance between the disk and the sieve band controls the flow and the capacity and may be adjusted by set screws. The coal is partially dewatered on the first screen and works down to the lower part of the band (under the influence of gravity, centrifugal force, and the slope of the screen), where it encounters a retaining band that checks its progress until a layer of coal builds up on the sieve band. Then the coal goes over the serrated rim, which redistributes it and allows it to fall to the next sieve band with considerable force. This drop is repeated at each new sieve band and is an important factor in the dewatering process. There are usually three or four sieve bands to a centrifuge. Since the diameters of the screen bands increase from top to bottom, the centrifugal force applied to the coal becomes greater the farther down the coal descends. This applies the most force where it is needed most, that is, just before the discharge of the material from the rotor. The area of each descending sieve band increases, allowing the coal to spread out more and more, which greatly facilitates dewatering. Dewatering is produced by impact and centrifugal force. The water passes passes through the screens, together with those solids smaller than the

30/ Barley, S. B., and Parmley, S. M., work cited in footnote 28, p. 407.

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screen openings, and is discharged from the drier at the bottom of the effluent chamber. The dried coal is discharged at the bottom of the drier into a delivery hopper.

The screen openings vary from 1/8 inch to 3/32 inch, depending on the moisture content desired. Since replacement of screens represents one of the principal operating costs, considerable experimental work has been done on this item. Stainless-steel screens are used now in several installations. Wear on the screens at impact zones is reduced by allowing a thicker coal layer to accumulate on the screen. The thicker bed, although it increases the moisture left in the product, materially reduces the amount of fines in the effluent. The cone-shaped basket of the Carpenter is lower and wider at the bottom than the cones of centrifuges employing scrapers, because the coal must descend under its own impetus. The greater slant of the screen makes the impact of the coal on the screen less direct and reduces wear. According to Chapman and Mott,[31] the Carpenter centrifuges employed at the Pueblo Works of the Colorado Fuel & Iron Co. have an average capacity of 100 tons per hour per unit. They require 75 horsepower and run at a speed of 360 r.p.m. Their dewatering is from an average moisture of 19.9 percent in the feed to an average moisture of 5.5 percent in the finished product.

Elmore Centrifuge

The Elmore centrifuge, which is illustrated in figure 3, has a screen basket with a vertical axis. The basket is cone-shaped but is higher and less spread out than that of the Carpenter. The basket has smooth sides and is not stepped, as is the Carpenter's rotor. Inside the basket is a rotating body fitted with scraping blades to keep the coal moving down the sieves. Both the basket and scraper rotate at high speed, but the scraper is rotated from 2 to 10 percent slower than the basket by means of differential bevel gearing. The effect is that the coal is slowly moved along by the blades and is discharged at the bottom. The scraper serves to remove the dewatered coal while the effluent passes through the sieve basket or screen and discharges into a launder. The distance between the scraper and screen is adjustable and controls the thickness of the coal bed on the screen. The distribution of the coal to the sieve is secured by a very flat cone, upon which the coal is fed and from which it is thrown by centrifugal force to the screens. The speed of rotation of the sieve body is about 550 r.p.m., and the 48-inch centrifuge used for coal drying has a capacity of 80 tons per hour. The moisture of the dewatered product at one plant averages about 7 percent. According to Prochaska,[32] the construction of the Elmore is exceedingly rigid, the base alone weighing as much as 6,000 pounds. The power requirement for the 48-inch size is only about 30 horsepower, which is considerably lower than that required for the Carpenter.

Hoyle Centrifuge

This is another vertical-axis centrifuge and its basket is in the form of a slightly conical cylinder. It has a scraping device in the form of a

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31/ Chapman, W. R., and Mott, R. A., work cited in footnote 26, p. 499.
32/ Prochaska, Ernst, work cited in footnote 22, p. 276.

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Figure 3.—The Elmore centrifuge (after Prochaska, Coal Washing, p. 276).

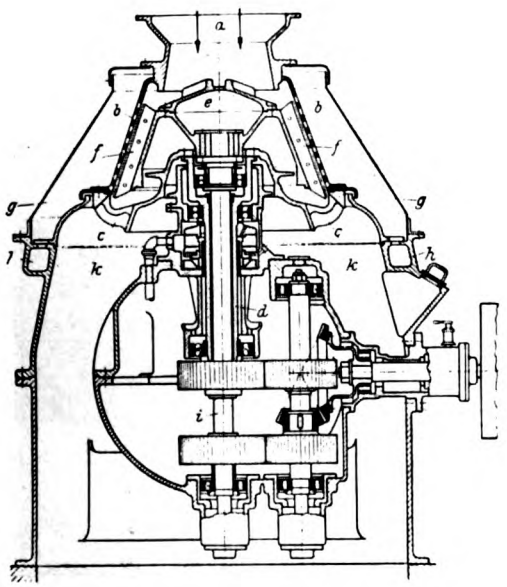

Figure 4.—The Reineveld centrifuge (after Glückauf, May 1937, p. 500).

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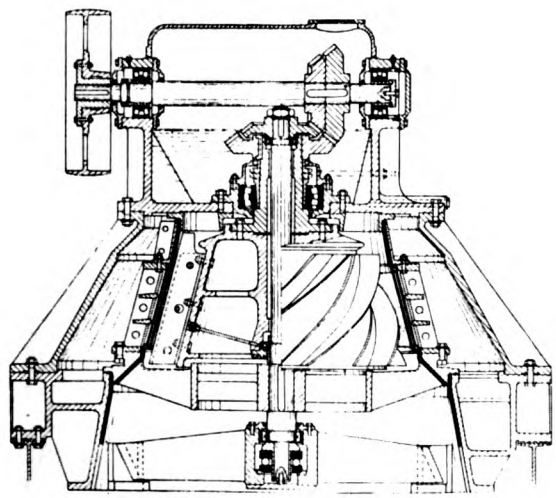

Figure 5.—The Wedag-Groppel centrifuge (after Glückauf, May 1937, p. 501).

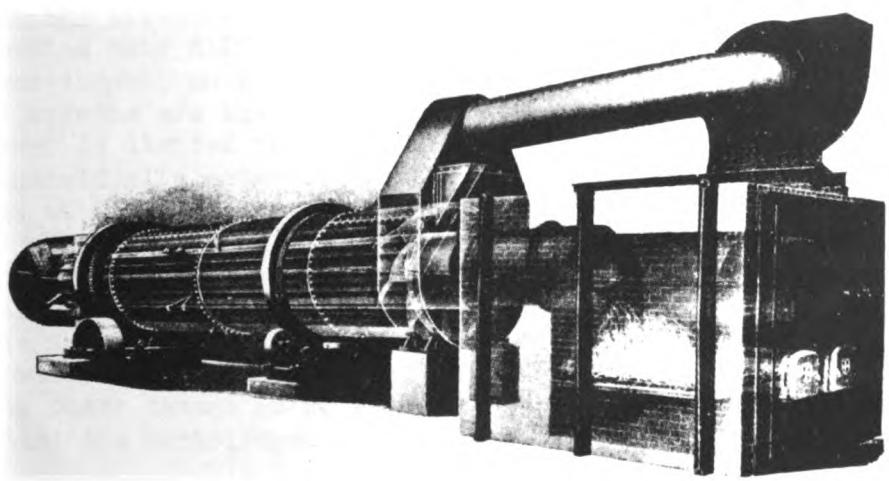

Figure 6.—The Ruggles-Coles dryer (courtesy of Hardinge Co.).

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spiral inside the basket. The pitch of this spiral increases as it goes down, so that the coal moves faster and is distributed in thinner layers as the dewatering proceeds. The later models of this centrifuge use steel wedge-wire screens and case-hardened parts to reduce wear.

Reineveld Centrifuge

The Reineveld and Wedag centrifuges are much used in Germany. The Reineveld, illustrated in figure 4, resembles the Elmore in shape of basket, scraper, and differential gears. The Reineveld uses perforated steel plates instead of screens. The perforations are 0.5 to 1.2 mm in diameter and they are countersunk from the outside, which helps to keep them from becoming clogged. The scraper body carries 16 knifelike blades and rotates 10 to 20 revolutions per minute slower than the perforated sieve body. The scraper blades are from 1 to 3 mm from the perforated plates, according to the size of the coal being treated. The distance between the blades and perforated plates may be changed by raising or lowering the scraper body. Operating practice, according to Rzezacz,33/ shows that a set of sieve plates will dewater 5,000 to 6,000 tons of hard coal and up to 13,000 tons of soft coal before renewal is necessary. The wear on the plates is greatest near the upper part, where most of the water works through, and this is true for any centrifuge of the vertical type. Rzezacz gives the following operating data: Rotor makes 730 to 750 r.p.m., power demand 25 to 32 kw., feed 23 to 34 percent water, centrifuged coal 6 to 8 percent water.

Wedag Centrifuge

The Wedag, illustrated in figure 5, is somewhat similar to the Hoyle, but it embodies many different features in its construction. The sieve body is cone-shaped, much like the Elmore or Reineveld, and has a vertical axis. The screens are interchangeable and easily replaceable. The protecting cover is divided into sections as is the sieve body, so that each sieve is individually accessible. The sieves have slotted openings with slot widths of 0.2 to 0.5 mm. The Wedag company claim that their latest pattern of sieve will work 25,000 to 30,000 tons of coal before showing any serious wear. The upper part of the scraper blades is exposed to the greatest abrasion, therefore the blades are made in two sections, upper and lower. The upper section is made of armor steel and its working life is thereby greatly lengthened. In one installation the rotor makes 500 to 515 r.p.m., the power demand is 20 to 27 kw., the feed contains 23.7 percent moisture, and the centrifuged coal 9.4 percent moisture.

Altpeter Gutehöffnungshütte Centrifuge

This is a sieveless dewatering centrifuge for slurry and fine coal. The coal is thrown against the walls of a drum rotor and the water flows out through orifices projecting into the coal. This method reduces the

33/ Rzezacz, P., work cited in footnote 27, pp. 296-507.

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amount of coal in the effluent and eliminates sieve replacement cost. It is one of the most recent centrifuges described in the literature.34/

The literature on centrifuges as applied to the dewatering of coal is likely to give the impression that there are many disadvantages connected with their use. They are said to be subjected to great wear, which necessitates frequent shutdowns for replacement of worn parts; and, since the centrifuge runs at a high speed, the repair work calls for the services of highly paid mechanics. However, all of the newer centrifuges use parts made of armored steel, case-hardened steel, or other resistant materials where heavy abrasion takes place. Screens are now made of steel or stainless steel, so that their wear is not such a serious factor as formerly. The individual screens are made to accurate specifications and are easily replaced when necessary. All of the centrifuges now leave a thin layer of coal on the screen, so that the screen is protected from direct impact, and this layer of coal serves to reduce the loss of fines by its filtering action. The considerable loss of fines from centrifuges appears to be an objection to their use, but modern practice has practically eliminated this objection. According to Rzezacz,35/ the latest practice in Europe is to pump the effluent to a clarifying tank and allow the fines to settle out. The first material to settle contains a high percentage of heavy pyrites, which can be drawn off and discarded, resulting in a distinct improvement due to reduction of sulphur. The next material, consisting of the better grade of fine coal, may be passed over a shaking screen to be dewatered and then be returned to the centrifuge. The fine slimes that do not settle are usually high in clay and may be discarded. Such a system, therefore, reduces the loss of fine coal and at the same time improves the quality of the coal. Everything considered, it seems likely that the use of centrifuges to dewater coal will increase in the future because they are capable of delivering a uniform product in respect to moisture.

Filters

For dewatering fine-coal sludge or froth flotation products, several types of filters are in use in this country and Europe. In American practice, the Oliver, Dorco, American vacuum, Genter vacuum, and the Laughlin centrifugal are used. In European practice, in addition to some of the preceding filters, the Wolf and Groppel are used. More recently, the Bloomco36/ is mentioned in the literature. Froth flotation of coal has proceeded farther in Europe than in the United States, and it is common practice to utilize pressure or vacuum-type filters. In the case of coal flotation concentrates that have been filtered, it is usually customary to dewater further by heat drying. The other field for the use of filters is in handling fine-coal sludge or slurry from thickeners or in handling fine refuse to prevent stream pollution. The latter use undoubtedly will increase the future. Flocculation with coagulating agents plays an important role in filtering.

34/ Colliery Guardian, Sieveless Dewatering Centrifuge for Slurry and Fine Coal: Vol. 148, 1934, p. 490

35/ Rzezacz, P., work cited in footnote 27, p. 505.

36/ Cullen, Wm., and Durant, H. T., The Separation of Solids from Liquids: Thickening: Coll. Guardian, London, vol. 149, 1934, pp. 1192-1195.

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HEAT-DRYING OF COAL

Theoretical Considerations Relating to the Heat-Drying Process

If a small quantity of water is placed in an air-tight vessel that has been evacuated, the water will evaporate and its vapor will diffuse until the space is filled completely. This evaporation will continue until the pressure of the water vapor has been raised to a limiting pressure that we shall call P'. This limiting value P' is called the saturation pressure and is constant for any given temperature. When the saturation pressure has been reached, no more of the liquid water will evaporate as long as the temperature remains constant. If not enough water is present to saturate the space, say only one-half the required amount, the water vapor will fill the space completely but will exert only one-half the saturation pressure. In such an instance the space occupied would be 50 percent saturated, or it would be said to have a relative humidity of 50 percent. Humidity is defined as the ratio of the quantity of vapor present to the quantity necessary to saturate at any given temperature. This ratio is usually expressed in percent.

Heat energy is required to change the state of the water from liquid to vapor; and if the temperature in the vessel is to remain constant, heat must flow through the walls of the vessel as long as evaporation is in progress. This heat energy causes the evaporation; it is absorbed in changing the water from liquid to vapor and does not cause the temperature to rise.

Now, if the vessel referred to above had not been evacuated but had contained a dry gas, then, on adding water, the water would have evaporated and filled the space as before, independent of the presence of the gas. When the vapor pressure had become equal to P', the vessel would be filled with the same amount of water vapor as was contained in the saturated space when no gas was present. The only difference would be that the internal pressure in the vessel would now be greater by an amount equal to the pressure exerted by the gas alone, for Dalton's law states that in a mixture of gases each exerts its pressure independently of the others.

$$P = P_G + P'$$

Where P = total pressure, P_G = pressure exerted by gas when alone, P' = saturated pressure of water vapor.

According to the above considerations, it is apparent that where evaporation is conducted in a small closed system where the water vapor has time to spread by diffusion, it is a mistake to consider the dry gas as the drying agent. Rather, it is the fact that the relative humidity has not reached 100 percent that makes the evaporation possible. The above considerations have been inserted to make the action of gases as driers easier to understand.

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To be of any real use in drying, a gas must be in motion. As an example, take the case of a tube or pneumatic drier. Here hot air and grains of coal are blown through a long tube and at the end the coal and air are separated by means of a cyclone. In this case the hot gas in contact with the coal supplied heat energy to vaporize the moisture in the coal, and at the same time the water vapor is swept out by the moving air. The action of hot gas as a heat-transfer agent is very important, for without it the coal would have to be heated by direct contact and by radiation.

Theoretically, the greater the velocity and temperature of the gas, the greater its drying action. However, in practical applications the velocity and temperature of the gas must be kept within limits, depending upon the individual installation. In all cases the temperature of the gas must not be high enough to change the chemical composition of the coal, and the velocity should not be high enough to cause excessive dust losses. The foregoing considerations apply particularly to the tube drier but are partially applicable to rotary and conveyor types as well. These driers do not depend on air currents to move their coal, but they do have a marked relative movement between coal and air. Sometimes the air moves with the coal and sometimes coal and air move in opposite directions. In any case, the water vapor is swept out by the force of molecular impacts coming from the moving air or gas. Heat is primarily the cause of the evaporation of moisture from the coal. This heat is transmitted by air or other gas that is brought directly into contact with the moist surface of the coal or indirectly through the walls of the container by radiation. It is essential that sufficient heat be supplied to raise and maintain the temperature of the drier against heat loss by convection and radiation as well as to provide heat for the evaporation of moisture content to the desired degree.

In recent years in the United States there has been a tendency, in several districts where the wet process is used for cleaning fine coal, to install heat driers in conjunction with mechanical dewatering devices for the reduction of moisture beyond that attainable solely by mechanical means. In some cases these driers have been installed to avoid shipping coal of such moisture content as to allow freezing or even hanging in bins or in railroad cars without freezing. In other cases, the heat driers have been used to meet the market requirements for pulverized fuel. In one instance heat driers are used in the preparation of coking coal, and in another as preliminary treatment for briquetting. In the case of slack, heat-drying of fine sizes is used to deliver a coal of low and uniform moisture content. Heat-drying by means of hot air or hot gases is used also in connection with shaking screens to supplement natural drainage on coarse coal.

Descriptions of Various Heat-Driers

The earliest and as yet most common type of heat-driers are the rotary type heated by steam or hot flue gases produced by gas or coal.

Types of these rotary driers at coal washeries in the United States are the Ruggles-Cole, Christie, and Rotary Louvre, which are illustrated

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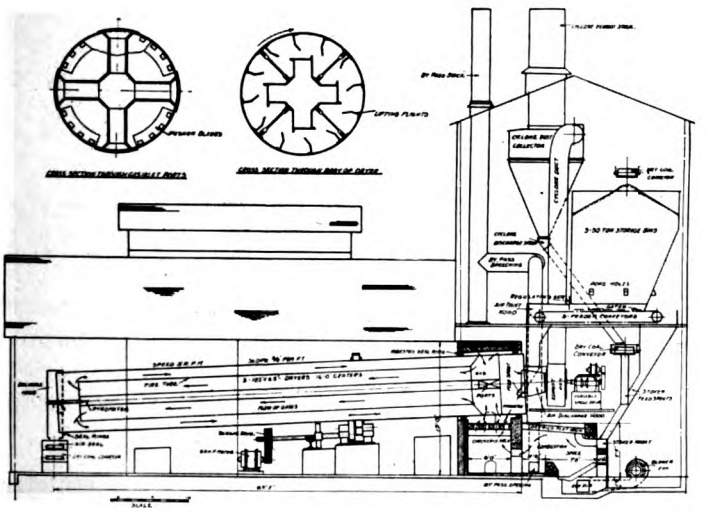

Figure 7.—The Christie heat dryer (courtesy of Pittsburgh Coal Co.).

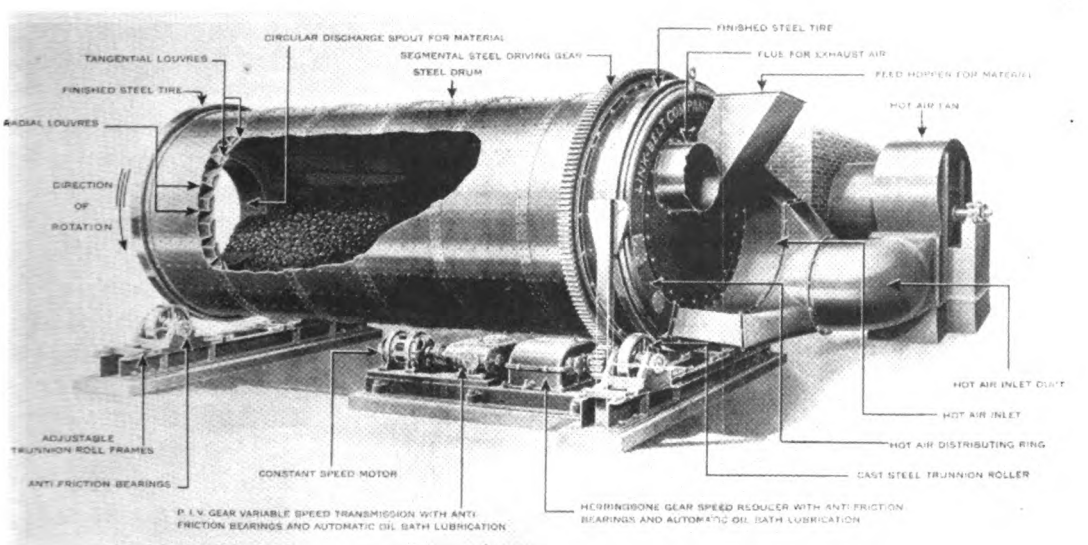
CIRCULAR DISCHARGE SPOUT FOR MATERIAL
TANGENTIAL LOUVRES
FINISHED STEEL TIRE
RADIAL LOUVRES
DIRECTION OF ROTATION
SEGMENTAL STEEL DRIVING GEAR
STEEL DRUM
FINISHED STEEL TIRE
FLUE FOR EXHAUST AIR
FEED HOPPER FOR MATERIAL
HOT AIR FAN
HOT AIR INLET DUCT
HOT AIR INLET
HOT AIR DISTRIBUTING RING
CAST STEEL TRUNNION ROLLER
ADJUSTABLE TRUNNION ROLL FRAMES
ANTI-FRICTION BEARINGS
CONSTANT SPEED MOTOR
P. I. V. GEAR VARIABLE SPEED TRANSMISSION WITH ANTI-FRICTION BEARINGS AND AUTOMATIC OIL BATH LUBRICATION
HERRINGBONE GEAR SPEED REDUCER WITH ANTI-FRICTION BEARINGS AND AUTOMATIC OIL BATH LUBRICATION

Figure 8.—The Rotary Louvre dryer (courtesy of Link-Belt Co.).

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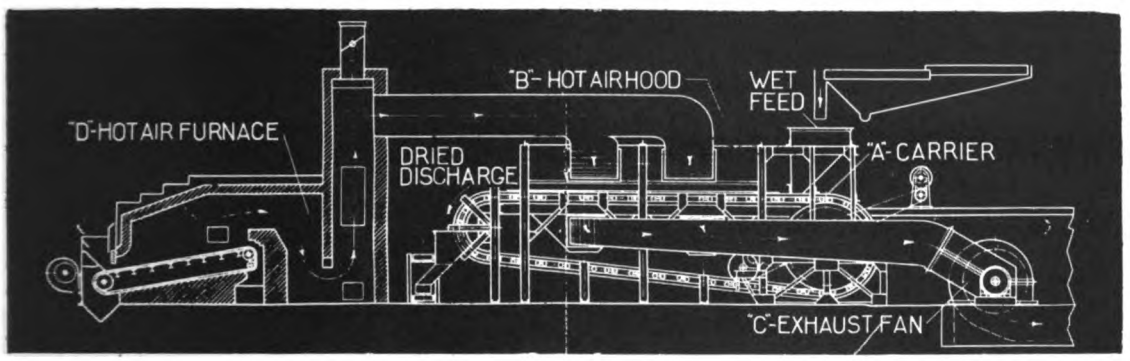

Figure 9.—The Dwight, Lloyd, Oliver dryer (courtesy of Oliver United Filters).

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in figures 6 to 8. In Europe, the Buttner, Rhineland, and Pehrson are used, according to Chapman and Mott.[37] They differ mainly in the manner of bringing the drying medium in contact with the moist coal and the method by which the coal mass is opened for contact of the heat with individual particles. In some cases the coal is heated directly by the cooler gases and indirectly by the hot gases. The hot gases are forced through the drier drums by exhaust fans, pressure fans, or both. Dust is caught in cyclone extractors. The rotation of the drum with a downward slope from the feed end to the discharge end, flights, and the draft furnish the means for transporting the coal through the drier. In some cases automatic hammers on the exterior of the shell and vibrators aid in breaking up caking on the flights.

Another type installed in this country is the D.L.O. drier, which is based on the principles of the Dwight Lloyd sintering machine and the Oliver filter. This drier is illustrated in figure 9. The wet coal is fed upon a continuous straight-line carrier made up of carrying screens, which passes the coal through a hot-air hood with one or more compartments. The hot air is forced through the coal bed by an exhaust fan and dries the coal by absorption and by sweeping the water from the particles due to the high velocity with which it passes through the coal bed (200 to 400 cubic feet per square foot of bed area per minute). The period during which the coal is subjected to the higher temperature is very short. The dried coal is discharged from the carrier onto a conveyor.

Another class of heat driers, used in Europe but not common in this country, is the vertical drier represented by the H. H., Lopulco, and Universal. These occupy less floor space than the horizontal types but have greater height. Most of these have a series of horizontal tables or shelves over which the hot gases or air pass; the coal is turned and progressed by rabble arms and passes from one shelf to another, being discharged at the lower end of the drier. The gases are removed by a fan through a cyclone in which the dust is collected. In general, with the vertical types lesspower is needed for the moving elements. The Bixby heat-drier is an example of a vertical drier installed in this country.

Finally, there is a class of pneumatic driers in which the drying medium serves also to transport the coal, such as the Buhler, Koon, Buttner Rapid, and Rema Rosin driers. The features of the pneumatic driers have been described recently by P. O. Rosin and E. Rammler.[38] They consist essentially in long steel tubes, through which the coal is blown by the hot gases. They have been used largely in connection with briquetting plants, drying of coal sludge, and grinding and drying of pulverized fuel in Europe. The simple one-stage drier consists of a furnace, feeder, drying tube, cyclone, and dedustor. More complicated flow sheets provide for recirculation and pulverization of the coal. The disadvantages of pneumatic driers are mainly the necessity for a uniform feed, which it is

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37/ Chapman, W. R., and Mott, R. A., work cited in footnote 26, pp. 503-504.
38/ Rosin, P. O., and Rammler, E., work cited in footnote 14.

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difficult to obtain with a damp, lumpy, or sticky material, and, second, the low efficiency of the drying in the discharge section of the tube.

In some coal-pulverizing plants the moist, fine coal is subjected to flash-drying by being passed through a rotary kiln before it is ground; in others, hot air is blown into the grinder to reduce the moisture content.

COSTS OF DEWATERING AND DRYING

It is difficult to secure information on the costs of dewatering and drying operations in the United States on a scale sufficient to give comparative costs. In the case of many coal-washing plants, the costs are not segregated, and in others the dewatering devices, such as conveyors with dewatering screens, bucket elevators with perforated buckets, or classifying screens, are used for dual purposes. Furthermore, the various degrees of dewatering attained and the wide combinations of sizes dewatered make a comparison of the costs at this time impossible, even in regard to centrifugal driers and heat-driers where these units serve no other purpose. For general information, the following approximate maintenance and operating costs for dewatering and drying are given:

Fine-coal shaking or vibrating screens,	$0.007	per ton coal discharged.
Centrifugal driers,	.025	per ton coal discharged.
Heat driers,	.07	per ton coal discharged.
Filters,	.04	per ton coal discharged.

The following cost data on dewatering and drying in European practice, published by the Reichskohlenrats[39] of Germany, are much more complete:

TABLE 1

Method for moisture reduction	Moisture reduction from percent	to percent	Quantity H_2O extracted, tons/day	Cost per ton put through *RM/t	Cost per ton of water extracted, *RM/t - H_2O
Rotary-drum driers	14	8	65.2	0.370	5.68
Tube driers.....	14	8	65.2	.417	6.30
Plate driers.....	14	8	65.2	.385	5.91
Rotary-drum driers heated with waste heat and supplementary gas fires	14	8	65.2	.194	2.98
Dewatering hopper	50	12	431.5	.111	.26
Coal centrifuges.	20	10	111	.154	1.39
Vacuum filter....	16	8	87	.113	1.30

*Note: The Reichsmark (RM) is quoted at present at approximately $0.40 United States currency.

39/ Reichskohlenrats, work cited in footnote 15, p. 80.

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These costs are the average for several plants that use the same type of dewatering and drying equipment.

GROWTH OF DEWATERING AND DRYING PRACTICE

The dewatering and drying of coal is a phase of coal preparation that, although practiced in some form for many years, has been studied more intensively in recent installations where fine coal is washed. Natural drainage has been practiced for years on screens or in bins or pits and is still the method of dewatering mainly used on coarser sizes in both anthracite and bituminous fields.

Elevators, drainage pits, and elaborate conveyor installations were often built where high moisture content was objectionable, particularly in the preparation of coal for coking. These were superseded at some plants by centrifugal driers as early as 1914, when the Elmore drier was developed and followed by the Wendel in 1915. The Carpenter centrifugal drier was developed about 1920 and installed shortly after that time in Colorado. Heat driers came into the picture of coal preparation with the installation of the Ruggles-Cole revolving drier in 1919 at a western plant. About 1930 the Christie rotary drier was installed at two places in the Pittsburgh district, and later the D.L.O. drier, an adaptation of the Dwight-Lloyd sintering machine, was developed and installed in the Indiana fields. Recent installations of heat driers include the Bixby, a vertical drier, and the Rotary Louvre drier, a type that has been used in Europe for several years prior to installation in this country.

The treatment of flotation concentrates and sludges necessitated the utilization of filters. The Laughlin filter was installed in the Pittsburgh district in 1923, followed shortly by the Dorr and Oliver and somewhat later by the Genter and American in the same district. For the thickening of sludges or the clarification of washery waters there are several types of settling tanks used. The Dorr thickener has been installed at many plants.

EXAMPLES OF AMERICAN DEWATERING AND DRYING PRACTICE

Pittsburgh District

The dewatering and drying practice in the Pittsburgh district is well illustrated by the installations at three plants.

At the Clairton[40] plant of the Carnegie-Illinois Steel Co., the dewatering units used consist of double-decked shaking screens equipped with 1/2-inch by 3/4-inch by 10-foot Perisertread screens on the top deck and with 3/8-inch round-hole screens on the lower deck. These screens receive the coarse metallurgical coal dixcharged from the main launders. The oversize from the screens contains 3.0 percent moisture. Similar shaking screens are used to dewater the coal from the rewashing launders. Two

40/ Seyler, H. W., Washing Coal for Coking Purposes at Clairton Byproduct Coke Works: Coal Age, New York, vol. 38, no. 6, June 1933, pp. 187-194.

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dewatering bucket elevators are used to handle the undersize coal from the raw-coal hummer screens and from the washed coarse-coal shaker screens preliminary to conveying to the fine-coal washing plants. The minus 5/16-inch washed fine coal is partially dewatered on wedge-wire screens after leaving the wash launder and then is further dewatered on two balanced-deck, dewatering, wedge-wire, shaking screens and a dewatering wedge-wire conveyor before centrifuging in Carpenter driers. The moisture reduction in the centrifugal driers is from 19.77 percent to 7.58 percent on 3/8-inch by 0 coal. The 0- to 3/8-inch refuse is dewatered by a bucket elevator before delivery to a refuse bin. Dorr thickeners are used to clarify the overflow from various parts of the operation. The underflow from the thickeners containing from 40 to 45 percent solids is dewatered on two Genter-type continuous filters, which reduce the moisture to 24.45 percent on the 0- to 20-mesh coal.

The Pittsburgh Coal Co. employs various types of dewatering and drying equipment at its washeries. Although these washeries differ in some details, the same types of dewatering units are in use at all wet-preparation plants. Coarse clean coal (3/8 inch by 4 inches) is dewatered and sized on high-speed shaker screens with heavy water sprays to wash the fine material through the screens, which aids dewatering. Further dewatering is obtained in some cases by wedge-wire screen sections in the troughs of the drag conveyors. The amount of dewatering depends primarily upon the area of the wedge-wire screen and the speed of the conveyor. For coal larger than 1 inch, the wedge-wire openings are 3/16-inch spaces, and for the 0- by 3/8-inch coal 1/8-inch openings are used.

The following results of dewatering coarse coal on conveyors are given by Barley and Parmley:[41]

41/ Barley, S. B., and Parmley, S. M., work cited in footnote 28.

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TABLE 2. - Drainage conveyor data and moisture in discharged product

Washed coal	Capacity Conveyor, t.p.h.	Size flight, inches	Length dewatering section, feet	Speed of conveyor, f.p.m.	Wedge wire				Percent moisture as loaded in railroad cars
					No. pieces	Width and length, inches	Size opening	Square feet	
3/8 x 4 inch	275	7 x 45	164	47	10	48 x 36	1/2 mm	120	3.0
2 x 4 inch	250	2-1/2 x 32	54	100	5	34 x 36	3/16 in.	42	2.3 to 1.5
1 x 2 inch	120	2-1/2 x 32	68	100	6	34 x 36	3/16 in.	50.5	3.1
3/8 x 1 inch	125	6 x 32	80	90	5	34 x 36	1/8 in.	42	4.5
3/8 x 1 inch	60	6 x 32	150	49	9	33 x 36	1/2 mm	74	3.8

Sizes are round-hole; all conveyors are drag-flight type.

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For the dewatering of fine coal (minus 3/8-inch), which is treated separately from the sludge, partial drainage is secured with shaking screens similar to the type used for coarse coal except that they are equipped with 1/5-mm phosphor-bronze wedge wire. Dewatering elevators also are used. Partial dewatering on the shaking screens or dewatering elevators is followed by dewatering on distributing conveyors with 1/2-mm wedge-wire dewatering sections.

The moisture reductions on the shaking screens, dewatering elevators, and fine-coal distributing conveyors are as follows:[42]

TABLE 3. - Moisture reduction and size relation of Minus 3/8-inch coal

Item	Moisture in feed, percent	Moisture in discharge, percent	Size ratio in feed[1]						
			4#	10#	14#	48#	100#	Minus 100#	Minus 48#
1. Dewatering elevator[2]	75.0	26.0	24.0	...	38.5	28.0	4.5	5.0	...
2. Dewatering screen[3]	75.0	18.0	18.0	...	42.5	31.0	5.5	3.0	...
3. Carpenter driers, AR-12 ..	[4] 22.5	6.5	24.0	...	38.5	28.0	4.5	5.0	...
4. Carpenter driers, AR-1A..	[4] 23.3	5.2	20.0	...	44.5	30.0	3.5	2.0	...
5. Carpenter driers, AR-1B[5]	19.0	9.1	19.5	...	36.5	31.5	7.5	5.0	...
6. Carpenter driers, AR-4[6]	20.2	7.2	...	69.3	8.7	20.0	...	...	2.0

1/ Tyler standard-screen sieves, sizes in mesh.
2/ Elevator discharges onto distributing conveyor, which feeds AR-12 driers.
3/ Dewatering screen discharges onto distributing conveyor, which feeds AR-1 drier (item 4).
4/ After passing over 9 feet of 1/2 mm wedge wire in distributing conveyor.
5/ Receives feed from dewatering elevator and storage bin.
6/ The AR-4 type, operating on Pittsburgh seam other than Pittsburgh Coal Co. and handling minus 5/16-inch coal.

The fine coal is further dewatered by Carpenter centrifugal driers with the results given in the preceding table. Details as to the Carpenter driers are given by Barley and Parmley.[43] In addition to the Carpenter driers, the Pittsburgh Coal Co. uses Christie driers further to dry the fine coal (minus 3/8 inch) and sludge. The feed[44] to the Christie driers consists of the discharge from the Carpenter driers (with a moisture content of 6.5 to 8.5 percent) with an additional smaller amount of filtered sludge averaging percent moisture, giving an average composite feed moisture of 7.5 to 9.5 percent. The discharge from the Christie driers has 3 percent moisture

42/ Barley, S. B., and Parmley, S. M., work cited in footnote 28.
43/ Barley, S. B., and Parmley, S. M., work cited in footnote 28.
44/ Parmley, S. M., Heat-Drying of Washed Coal: Trans. Am. Inst. Min. and Met. Eng., Coal Division Volume, 1931, pp. 336-351.

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After leaving the Dorr thickener, the sludge, which is minus 28-mesh, is dewatered by Oliver- and Dorr-type vacuum filters and Laughlin centrifugal-type filters. The dewatered products from the filters, with a moisture content of 20 to 24 percent, is mixed with the minus 3/8-inch product from the Carpenter driers and is heat-dried.

The Nemacolin plant of the Buckeye Coal Co., a subsidiary of the Youngstown Sheet & Tube Co.,[45] is also an example of a system that embraces various methods of dewatering and drying. Shaking screens are used to dewater 3/8-inch by 4-inch coal to approximately 2.5 percent moisture. Carpenter driers are used to dewater minus 3/8-inch to 48-mesh coal to about 22 percent moisture. In addition, some minus 4-inch coal is dried in a Christie drier to approximately 2.5 percent moisture.

In the coarse-coal dewatering, screens with 5/16-inch round holes are used, and for the fine coal, shaking screens 1/5-mm wedge wire are used. The oversize from the fine-coal dewatering screen forms the feed of the Carpenter driers. The effluent from the Carpenter driers is dewatered in an additional Carpenter drier unit with 1/16-inch perforated plates.

The feed to the fine-coal dewatering shakers is partially dewatered by passing over a fixed wedge-wire screen in the launder.

The feed to the two 8-foot 6-inch American suction filters consists of the underflow from the Dorr thickeners containing about 45 percent solids.

Illinois

In Illinois, several new washers of large capacity have been built in recent years. In each case some provisions have been made for dewatering and drying.

The Sahara Coal Co., at their new Harrisburg plant, which is designed to handle 825 tons per hour, dewaters the coarse coal (plus 3/4-inch) on the washed coal-classifying screens. The 3/4-inch by 0 coal is dewatered on a 5/16-inch vibrating screen to make a 3/4-inch by 5/16-inch product; the minus 5/16-inch by 0 from this screen is partially dewatered on a 1/2-mm dewatering screen, and then the 5/16-inch by 1/2-mm product is dried in Christie driers.

The flow sheet[46] of the 600-ton-per-hour wet preparation plant of the United Electric Co. at Fidelity, Ill., shows the use of shaking screens for classifying and dewatering their 3- by 2-inch, 2- by 1-1/4-inch, 1-1/4- by 3/4-inch, 3/4- by 5/16-inch, and 5/16- by 1/4-inch sizes. The minus 1/4-inch washed coal is partially dewatered in a washed-coal boot by a drainage elevator and then on vibrating screens, which remove the minus 48-mesh material. The 48-mesh by 1/4-inch washed coal is further dewatered in Carpenter driers to about 13 percent moisture. A stationary dewatering

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45/ Coal Age, vol. 36, no. 8, August 1931, pp. 408-411 and 414.
46/ Coal Age, vol. 40, no. 5, pp. 197-200.

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screen with 1/5- and 1/4-mm wedge wire is used on the regulating material from the fine-coal unit. Short wedge-wire sections are placed in the fine washed coal conveyors. The minus 48-mesh material goes to a Dorr thickener, and the thickened sludge of 35-percent solids is pumped to 60-mesh Gyrex vibrating screens, where the oversize passes to the refuse conveyor and to railroad cars for waste disposal and the undersize is sluiced to the pond. The drier effluent is screened on a stationary, 48-mesh, wedge-wire screen. The oversize is returned to the drier units and the undersize is delivered to the Dorr thickener. No minus 48-mesh coal is recovered.

The Wilmington plant of the Northern Illinois Coal Mining Co. provides for both dewatering and drying of coal. This plant represents a comparatively recent installation, in which the drying and dewatering of fine coal is given particular attention. In this plant of 500-tons-per-hour capacity, the overflow from the main and rewash launders is dewatered on a three-deck, washed-coal, sizing and dewatering shaking screen, which makes the following products: 3- by 3/4-inch, 3/4- by 5/16-inch, 5/16- by 3/16-inch, and 3/16-inch by 0.

The coarse coal, 3/4- by 3-inch, is dewatered further on a multideck sizing screen. Two Carpenter centrifugal driers partially dewater the 3/16-inch by 48-mesh 27 percent to 7 percent. The effluent from the Carpenter driers is dewatered on a vibrating screen. The dewatered product from the Carpenter driers is dried further in a 7- by 45-foot Christie rotary heat drier to 2 percent moisture. The 1/4- by 3/4-inch washed coal is dried in a 4- by 20-foot, D.L.O., continuous-heat drier from 7 to 1 percent moisture.

Ohio

The new Willow Grove No. 10 preparation plant[47] of the Hanna Coal Co. has a rated capacity of 180 tons per hour; it is an excellent example of modern dewatering and drying procedure and is designed to give uniform products in regard to both chemical and physical characteristics in all sizes. This plant is near St. Clairsville, Ohio, and ships primarily lump, egg, nut, and stoker coal.

Dewatering of the washed coal is accomplished on two classifying screens mounted one above the other and hung on flexible wooden hangers. The arrangement of the perforated steel-plate screens allows a series of products to be made, including 4- by 2-inch, 2- by 1-1/2-inch, 1-1/2- by 1/2-inch, 1/2- by 3/16-inch, and minus 3/16-inch sizes. Water sprays are used on these classifying screens. The minus 3/16-inch coal and the water are run to a Dorr hydroseparator or thickener, which separates the 3/16-inch by 28-mesh material from the minus 3/16-inch fines. The 3/16-inch by 28-mesh product is dewatered on dewatering shakers with 1/2-mm, stainless-steel, wedge-wire screens. The minus 28-mesh fine coal is pumped to a settling cone, from which the slurry either can be pumped to a settling pond or be filtered by an American continuous filter. The filter cake is

47/ Given, I. A., Preparation Efficiency: Coal Age, vol. 42, no. 10, October 1937, pp. 65-71.

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combined with the fine sizes from the classifying screens and dewatering shakers for drying.

The drying equipment at this plant consists of a link-belt, rotary, Louvre drier for the minus 1/2-inch washed coal. Hot air at about 930° F. is supplied to the drier from a pulverized-coal furnace. The drier, which is designed to evaporate 9,000 pounds of water per hour from 40 tons of washed coal, is 10 feet 6 inches in diameter and 30 feet long.

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